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TECHNICAL REPORT

SITE INFLUENCES ON THE XM76 GRID

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U.S. ARMY DUGWAY PROVING GROUND

DUGWAY, UT 84022

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The XM76 Grid is a new testing location on Dugway Proving Ground where terrain and meteorological tower influences on meteorological measurements have not been previously analyzed. The primary objective is to quantify site influences on wind and turbulence data collected at the XM76 Grid. A secondary objective is to evaluate the capability of Smith and Turner stability categories to order turbulence data. Sigma A/Sigma E ratios are used to quantify terrain influences at low and high wind speeds for fetches over low, moderate, and high roughness terrain. Tower shadowing effects on wind and turbulence measurements are also quantified as a function of wind speed. Preliminary analysis of Smith versus Turner stability category techniques indicates superiority of the Smith technique for the horizontal component of turbulence.

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SITE INFLUENCES ON THE XM76 GRID

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SITE INFLUENCES ON THE XM76 GRID

1. INTRODUCTION

The XM76 Grid is a newly constructed grid in frequent use during the past year as a principal site for smoke munitions tests. The micrometeorological data collected at this site have been closely monitored by meteorologists to insure data quality. The wind and turbulence data from this grid reveal influences other than that due to the local micrometeorological setting. These influences include increased variability in horizontal wind angle measurements due to terrain, reduced wind speed measurements, and increased turbulence due to the towers supporting the meteorological equipment.

The purpose of this note is to quantify the tower and terrain influences on the XM76 Grid meteorological data. An evaluation of Smith (1972) versus Turner (1964) atmospheric stability classification procedures is described. The results should provide analysts utilizing XM76 grid meteorological data with a measure of tower and terrain influences and should also acquaint test officers with alternative stability category calculation techniques to be used for test day go/no-go decisions.

2. SITE DESCRIPTION

The U.S. Army Dugway Proving Ground (DPG) XM76 grid is located on flat clay soil in what was formerly the bottom of Lake Bonneville. Terrain in the vicinity of the XM76 Grid is generally flat and uniform in all directions to a distance of 100 times instrument height of 16m. The greatest elevation differences on the Grid are 1 meter deep drainage ditches alongside access roads. Grey Molly, a desert shrub 7 to 30 cm in height, is the primary vegetation. These shrubs are typically spaced at 1 to 2 meter intervals. The Grid has a shallow downward slope to the northwest and an elevation of 1309 meters above mean sea level. Site roughness is estimated at 2 to 4 cm. The XM76 Grid and surrounding geographical features are shown in Figure 1.

While the terrain in the immediate vicinity of the XM76 Grid is flat in all directions, significant topographic features are located several kilometers from the Grid. The major terrain features can be grouped into three sectors. In the sector 290 degrees clockwise to 120 degrees there are clusters of small sand dunes 2-4 meters in height at distances of 2-5 kilometers from the Grid. Also, the Cedar Mountains lie in this sector at a distance of 20 kilometers, with rises of 500-800 meters above grid level. The 120 to 180 degree sector is flat and contains no significant terrain features within 20 kilometers of the grid. The condition of horizontal homogeneity is approached in this sector due to the absence of terrain roughness

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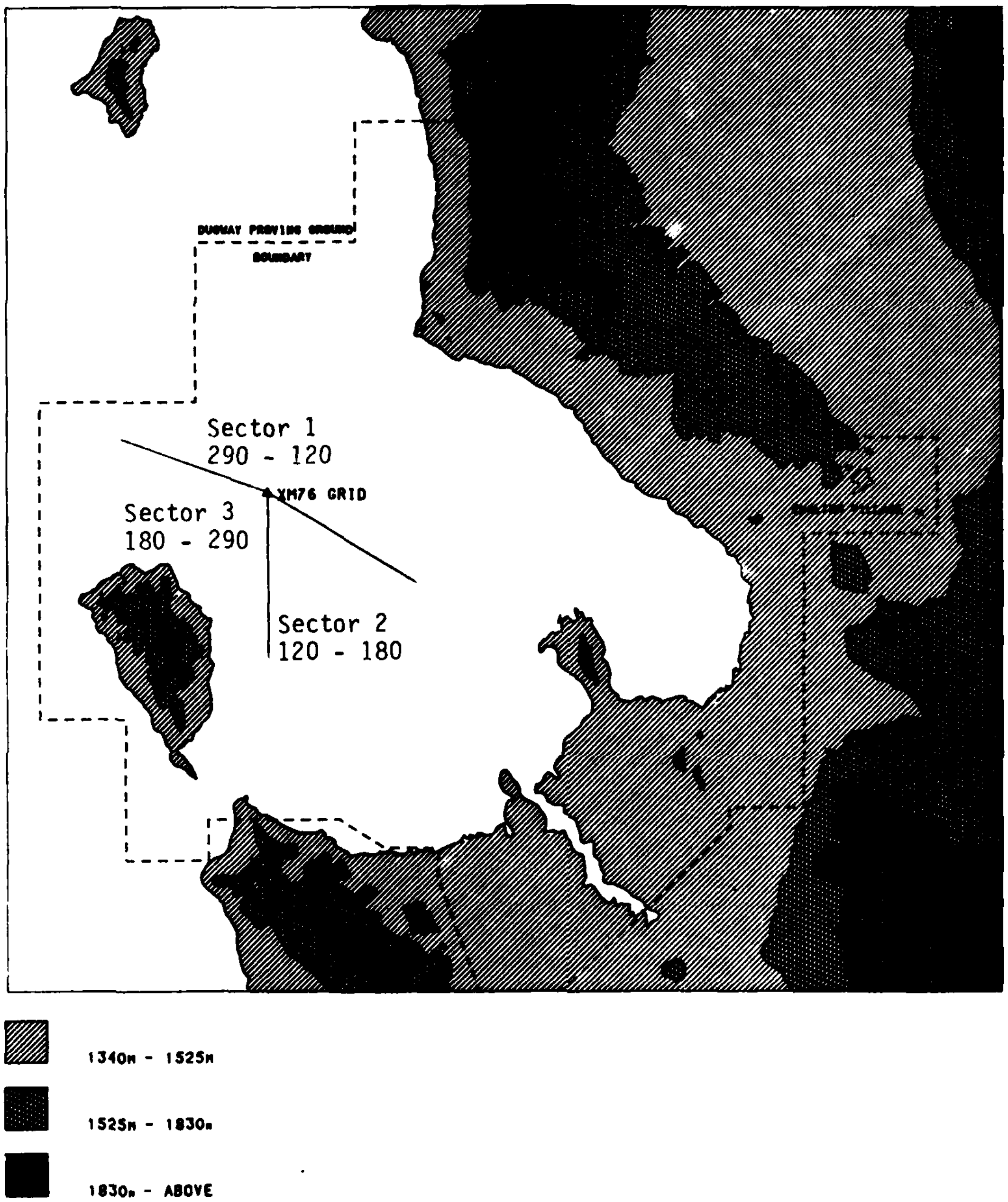

FIGURE 1. The XM76 Grid and surrounding geographical features.

discontinuities. Granite Mountain, at a distance of 8 to 10 kilometers from the grid, dominates the sector from 180 through 290 degrees. This is the largest terrain feature near the XM76 Grid, with rises about 800 meters above grid level. This terrain feature is a major roughness element. The effects of Granite Mountain will become apparent in the analysis of meteorological data described below.

The XM76 Grid is particularly useful for meteorological analysis of tower and terrain influences because two 32-meter meteorological towers are spaced 500 meters apart on the Grid. These towers were instrumented with meteorological equipment on boom arms extending several meters from the northwest and southwest sides of the towers, as shown in Figure 2. The boom arms were located to maximize exposure of meteorological equipment to desired wind directions (e.g., northwest and southeast). Shadowing of the sensors by the tower is inevitable due to tower dimensions. To study the effects of tower shadowing, data from the XM76 Grid north and south tower were divided into three groups. For the sector from 340 to 030 degrees, a shadowing effect was suspected for the south tower. For the sector from 110 to 160 degrees, a shadowing effect was suspected for the north tower. The sectors from 030 to 110 degrees and and from 160 to 340 degrees were expected to show no tower influence and data from these sectors were combined in the analysis.

3. AVAILABLE DATA

Data utilized in this study were collected from October 1984 to April 1985. These data were the standard 10-minute averaged line printer data that is routinely printed out in the meteorology data center for test support and quality control on days when testing occurs on the XM76 grid. These data were not available during periods of unfavorable weather conditions, holidays, weekends, or equipment outages and do not represent a "climatology" of XM76 Grid meteorological conditions. However, this data set is a substantial sample of micrometeorological data collected during a variety of conditions at the XM76 grid site and is therefore worthy of analysis. In order to avoid accumulating vast amounts of similar data, only one 10-minute sample during each hour of data collection was included in the analysis.

The data of interest in this analysis were primarily means and standard deviations of speed and direction measurements obtained from Climet Model 011-1 anemometers and Model 012-11 bi-directional vanes. The characteristics of this equipment are presented in Table 1 below.

Data collected at the XM76 Grid meteorological towers are transmitted via hardwire to an HP2250 computer that logged the data on magnetic tape and performed basic averaging to obtain 1

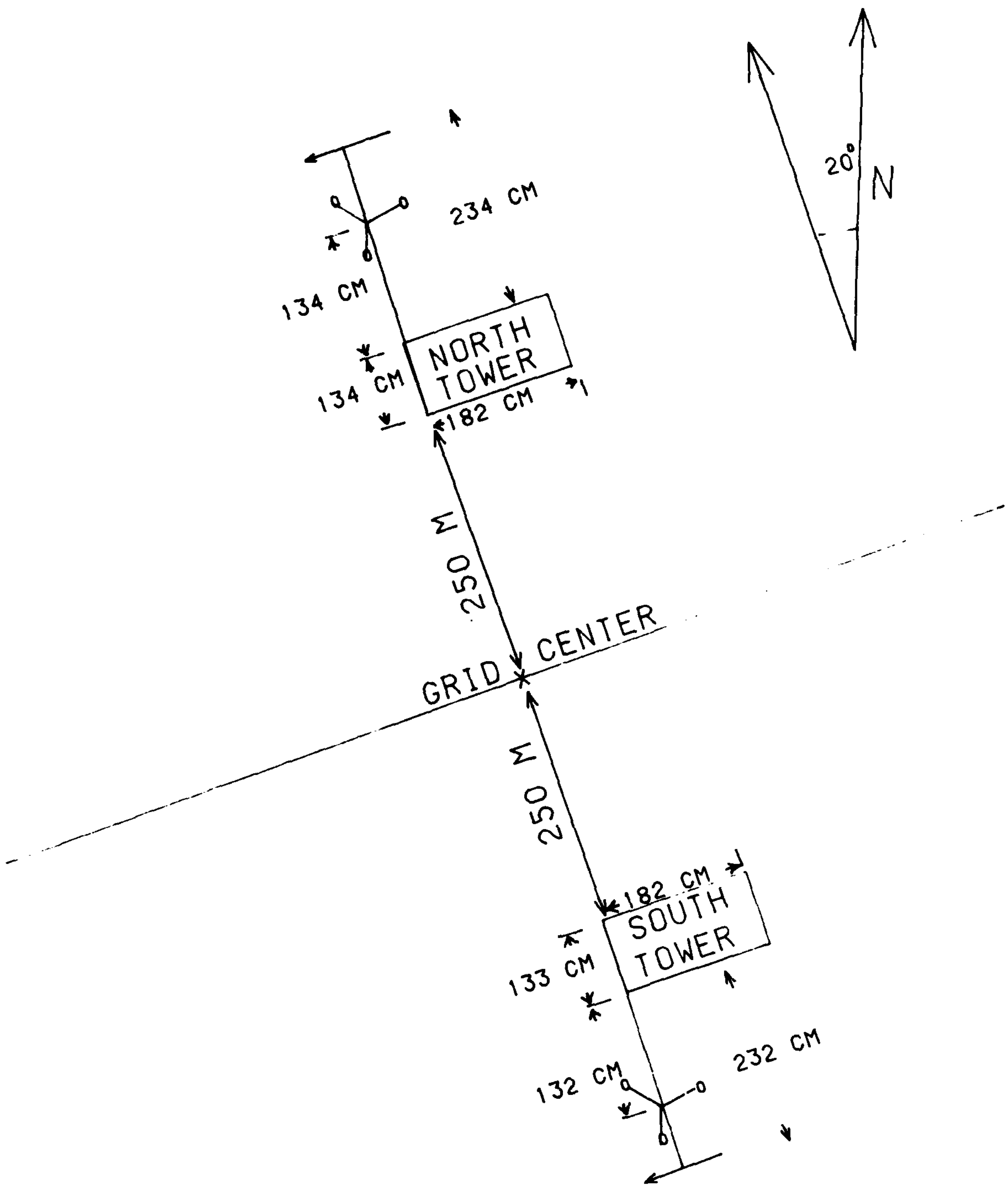

FIGURE 2. XM76 Grid Meteorological tower dimension and decoration scheme.

TABLE 1.

Characteristics of the Climet Model 011-1 anemometer and Model 012-11 Bi-directional Vane Transmitters.

	MODEL 011-1	MODEL 012-11
THRESHOLD	0.6 mph	0.75 mph
DISTANCE CONSTANT	5 ft.	3.13 ft
DAMPING RATIO	-----	0.6
ACCURACY	+/-1% or 0.15 mph	+/-2 degrees
WEIGHT	14 oz	25 oz
OUTPUT (full scale voltage)	10 V square wave	4.8 V horizontal 1.6 V vertical

second averages and conversion from voltages to engineering units. The data are then transmitted via telephone modem to HP1000 computers in the data central computer center located in Building 4126 where 10-second averages are obtained and stored on back-up tape. Ten-minute averages of the ten-second averaged data are also printed for test control purposes. Although 10-minute samples of the 10-second averaged data do not represent high frequency turbulence data, standard deviations of the horizontal and vertical wind angle measurements provide an estimate of turbulence intensity and were judged suitable for basic analysis of tower and terrain influences.

For this analysis, one 10-minute sample obtained from the line printer data was recorded for each hour of data collection. Only daytime trials were used because there were too few night measurements for an adequate sample size. Wind direction, speed and standard deviation were recorded for the 2,4,8 and 16 meter levels on each tower. Suspect data were identified and removed from the analysis. The mean and standard deviations of the 16-meter level wind were chosen for analysis because the data measurements at this level were judged to be the most complete.

4. ANALYSIS

a. Terrain Influences

To analyze for terrain influences, the data were grouped in sectors according to fetch over the various terrain types. As described in section 2, the sector from 290 to 120 degrees included a fetch of intermediate roughness over sand dunes, the sector from 120 to 180 degrees has a fetch over relatively uniform low-roughness terrain, and the sector from 180 through 290 degrees included Granite Mountain as a major terrain element. Analysis for terrain influences requires that other influences such as surface heating, tower influences, and stability be eliminated, or at least minimized. This was accomplished by computing ratios of Sigma A to Sigma E from data measure at the 16-meter level on each tower. While minimizing unwanted tower and stability influences, it is assumed that these ratios increase as terrain features preferentially add eddy energy to the Sigma A turbulence component.

A statistical evaluation (t-test) was performed on the Sigma A/Sigma E ratio data grouped by wind direction sectors. For t-test intercomparisons these sectors were designated as sector 1 (290-120 degrees), sector 2 (120-180 degrees), and sector 3 (180-290 degrees). The data and significance test results are summarized in Table 2. Data in Table 2 are stratified into light (<2m/sec), strong (>5m/sec), and all wind speed groups, demonstrating the wind speed contribution to terrain influences. The "all" wind speed class includes the light, strong, and wind speeds in the intermediate 2 to 5 meter/second range.

TABLE 2.

Terrain influences on the ratio of Sigma A to Sigma E for the south/north towers.

WIND DIRECTION SECTOR	NUMBER OF CASES (N)	MEAN ($\bar{X}$)	STANDARD DEVIATION (S)	SECTOR NUMBER	SIGNIFICANT "T" SCORE *
Light winds (< 2.0 m/sec)					
290° -120°	51/52	1.7/1.9	0.9/1.1	1	NONE
120° -180°	18/18	1.8/2.5	0.7/1.2	2	S/N
180° -290°	09/09	2.3/2.2	1.2/1.0	3	NONE
SUM	78/79	1.8/2.1			
Strong winds (>5.0 m/sec)					
290° -120°	44/44	2.6/3.0	1.3/1.8	1	1-3,2-3/
120° -180°	18/18	2.3/2.1	0.9/0.6	2	1-2,2-3
180° -290°	09/09	3.8/3.5	1.3/1.2	3	
SUM	71/71	2.7/2.8			
All cases					
290° -120°	178/177	2.3/2.3	1.1/1.4	1	1-3/1-3
120° -180°	66/66	2.4/2.5	2.0/1.5	2	
180° -290°	24/25	3.1/3.0	1.6/1.9	3	
SUM	268/268	2.4/2.4			

*See text for an explanation of notation in this column.

Because the sample size (N) from Table 2 ranges from 9 to 178, the appropriate test of significance was the two tailed t-test, based on the student's t distribution. The purpose of the test was to determine whether statistically significant Sigma A/Sigma E ratio differences exist for the chosen wind direction sectors and wind speed stratifications. For this test, a null hypothesis (H_o) and an alternative hypothesis (H_a) were chosen where:

H_o: The ratio data from Table 2 arose from the same underlying population and there are no significant differences between the samples.

H_a: The tested ratio data originated from significantly different populations.

The level of significance was set at 5%.

The statistics used for the significance tests were calculated using Equations 1 and 2:

$$S = ((N_1 \cdot S_1 + N_2 \cdot S_2) / (N_1 + N_2 - 2))^{1/2} \quad (1)$$

$$T = (\bar{X}_1 - \bar{X}_2) / (S \cdot (1/N_1 + 1/N_2)^{1/2}) \quad (2)$$

The sample means ($\bar{X}_1$, $\bar{X}_2$), standard deviations (S_1, S_2), and sample sizes (N_1, N_2) are given in Table 2. The calculated T statistics were then compared using a two-tailed test at a 5% level of significance using the student's t distribution. The hypothesis H was rejected in each case where T fell outside the range $-t_{.975}$ to $t_{.975}$ for ($N_1 + N_2 - 2$) degrees of freedom. The convention used in this report is for uppercase T to represent the score and lower-case t to represent the test.

The t-test was first applied to corresponding data from the south and north tower data sets to determine if a significant tower influence was present. With one exception, Ho could not be rejected. The exception was sector number 2 (120-180 degrees) for the light wind cases, where differences between the means (1.8 vs 2.5) proved to be statistically significant. Using Sigma A/Sigma E ratios apparently minimized, but did not eliminate, tower influences on the data.

To evaluate the significance of terrain influence, T scores were calculated between sectors 1-2, 2-3, and 1-3 for each wind speed stratification on the south tower and again on the north tower. Significant inter-sector T scores are presented in the

right hand column of Table 2. No significant inter-sector T scores occurred during light winds. In contrast, significant inter-sector T scores occurred during strong winds, and significant T scores occurred between sectors 1 and 3 for the "all" wind speed category.

To evaluate the influence of light versus strong wind speeds, sector to sector T scores were also evaluated between the light and strong wind cases. Significant T-scores occurred within the 290 to 120 and 180 to 290 degree sectors, but scores were not significant for the 120 to 180 degree sector with flat upwind terrain.

A number of inferences can be drawn from the t-test results. One inference is that terrain upwind from the grid exerts little influence on the turbulence ratios under light wind conditions. Turbulence intensity on the XM76 grid is not a function of wind direction for light winds. Conversely, significant terrain influences are evident on the turbulence ratios measured under strong wind conditions. The mean Sigma A/Sigma E ratios increase as a function of wind speed, except when winds are from the 120 to 180 degree low-roughness sector where changes with wind speed were not significant. A second inference is that the Sigma A/Sigma E ratios increase as a function of roughness. The ratio for the 180 to 290 degree sector, which included Granite Peak, is 3.65, compared to a ratio of 2.2 for the flat 120 to 180 degree sector. The average ratio is 2.8 for winds from the 290 through 120 degree sector where the fetch is over moderately rough terrain.

b. Tower Influences

The influence of the tower structure on the 16 meter winds was determined by dividing the south tower 10-minute averaged wind speed measurements by the corresponding north tower measurements. The resulting ratios were then grouped by sectors according to expected tower shadowing effects. The south tower shadowed anemometer measurements for winds coming from the 340 - 030 degree sector. Wind speed ratios determined from this sector were expected to be systematically less than 1.0. The north tower anemometer measurements were shadowed when winds were from 110-160 degrees. Wind ratios for measurements from this sector were expected to be systematically greater than 1.0. The remaining sectors, 030 to 110 and 160 to 340 degrees, were expected to approach 1.0. Results for low, high, and all wind speed cases are summarized in Table 3. The mean, $\overline{X}$, and standard deviation, S, for each wind speed group were computed. The t-test scores were also calculated.

Significant T scores were not obtained for interactions between any of the sectors under light wind conditions. In contrast, significant T scores were obtained for interactions between all sectors during strong winds. The inference is that the tower influence becomes significant with higher wind speeds

TABLE 3.

Tower influences on south/north tower 16 meter wind speed ratios.

WIND DIRECTION SECTOR	NUMBER OF CASES (N)	MEAN ($\bar{X}$)	STANDARD DEVIATION (S)	SECTOR NUMBER	SIGNIFICANT "T" SCORE *
Light Winds (< 2.0 m/sec)					
340°- 030°	22	0.965	0.202	1	NONE
110°- 160°	20	1.064	0.266	2	NONE
030°- 110°, 160°- 340°	41	1.050	0.261	3	NONE
SUM	83	1.031			
Strong Winds (> 5.0 m/sec)					
340°- 030°	28	0.911	0.054	1	1-2,
110°- 160°	15	1.089	0.072	2	2-3,
030°- 110°, 160°- 340°	27	1.016	0.065	3	1-3
SUM	70	0.990			
All Cases					
340°- 030°	91	0.914	0.118	1	1-2
110°- 160°	55	1.084	0.178	2	
030°- 110°, 160°- 340°	125	1.039	0.181	3	
SUM	271	1.006			

*See text for an explanation of notation in this column.

under these circumstances. A 9 percent average reduction in apparent wind speed due to tower shadowing is noted in all data. For all wind speeds combined, the T score for the 340 to 030 degree sector (south tower shadowed) and the 110 to 160 degree sector (north tower shadowed) is significant.

The ratio between the mean wind speeds measured on the south and the north towers for the sectors where no shadowing was expected (030 to 100 degrees and 160 to 340 degrees) is 1.039 for the combined ("all" cases) data. Similar ratios for these sectors under light and strong winds also exceed unity. It is doubtful that wind at the south tower were systematically higher than at the north tower when averaged over the entire period of data collection. Consequently, this result suggests the existence of a difference in the response of the south and north tower 16 meter anemometers. A t-test was used to evaluated the significance of the samples' departure from a "no difference" population, with a population mean (μ) of 1.0. T was calculated using Equation 3

$$T = ((X-\mu)\ (N-1)^{\frac{1}{2}})/S \qquad (3)$$

and compared to Students' T scores with N-1 degrees of freedom at the 5% level of significance. The results were significant for the cases when all wind speeds were considered, but below the level of significance for the light and strong wind case. The inference drawn from these tests is that the response of the north and south tower anemometers was *significantly different*, although the difference was not detectable during calibration. The differences were apparently greatest (near 5 percent) at low wind speeds, decreasing to less than 2 percent during high winds.

The effects of tower shadowing on turbulence measurements were also examined. The effects of extraneous influences were minimized by dividing the Sigma E measurements from the south tower by those concurrently measured on the north tower. The means and standard deviations of these ratios are presented in Table 4.

The T scores from sector 3 were tested for significant differences from unity by employing the same t-test procedure used on wind speed ratios described in previous paragraphs. No significant T scores were calculated for the light wind cases and for cases in which all wind speeds were considered. The T score for high wind speed cases (in sector 3 where the mean ration is 1.145) was significant and anomalous. The mean ratio calculated for sector 3 exceeds the mean ratio for sector 2 where the anemometer on the north tower was shadowed (1.114).

Results from Table 4 reveal a significant depression of Sigma E by tower shadow effects as evidenced by the ratios less

TABLE 4.

Tower influences on south/north tower 16 meter Sigma E ratios.

WIND DIRECTION SECTOR	NUMBER OF CASES	MEAN ($\bar{X}$)	STANDARD DEVIATIONS (S)	SECTOR NUMBER	SIGNIFICANT "T" SCORE *
Light Winds (< 2.0 m/sec)					
340° - 030°	20	0.992	0.360	1	1-2,2-3
110° - 160°	18	1.558	0.520	2	
030° - 110°, 160° - 340°	30	1.000	0.481	3	
SUM	68	1.145			
Strong Winds (> 5.0 m/sec)					
340° - 030°	28	0.960	0.322	1	1-3
110° - 160°	15	1.114	0.389	2	
030° - 110°, 160° - 340°	27	1.145	0.341	3	
SUM	70	1.064			
All Cases					
340° - 030°	87	0.868	0.353	1	1-2,2-3
110° - 160°	52	1.298	0.526	2	1-3
030° - 110°, 160° - 340°	116	1.002	0.440	3	
SUM	255	1.017			

*See text for an explanation of notation in this column.

than and greater than unity respectively for sectors 1 and 2 in the Table. This is likely due to break-up of larger scale eddies by the tower structure. Tower wake effects on Sigma E are significant even at low wind speeds where the effects on wind speed data were below the level of significance.

c. Comparison of Two Methods for Defining Pasquill Stability Category.

A comparison study of two different methods for determining Pasquill stability categories was conducted utilizing the meteorological data from the XM76 Grid. The Pasquill stability categories are determined using the Turner (reference 1) method based on the estimated cloud height, percent of cloud cover, and the 8 meter winds measured at the XM76 Grid. The Smith method (reference 2), also used for determining the Pasquill stability, requires an incoming solar radiation measurement and the 8 meter wind speed.

Sigma E and Sigma A are used to evaluate the relative performance of the Smith and Turner stability classification methods. Stability classification methods provide turbulence estimates when measurements are unavailable. The performance of stability classification method can be evaluated on the basis of how well the methods discriminate differing turbulence conditions. The performance evaluation was designed to address the following questions:

(1) Are the mean turbulence categories sufficiently well separated and is the scatter within each category sufficiently small to produce significant differences between the categories?

(2) Do the Smith and Turner methods produce a significantly different result?

Answers to the above questions are examined below using two-way analysis of variance.

To proceed with the analysis of variance, Pasquill stability categories are derived using the Smith and Turner methods and matched with the corresponding Sigma A and Sigma E calculations. Means and standard deviations are computed for each of the categories. This procedure was used for 16-meter Sigma A and Sigma E values for both the North and South towers. The results are presented in Tables 5 and 6.

Tables 5 and 6 present the mean ($\overline{X}$) Sigma E and A values and the standard deviation (S) of sigma values within each Pasquill category. The number of cases (N) within each group represents the number of valid data points. Using the Turner method, all of the Sigma data fell within categories B, C, and D. A few cases fell within Pasquill stability category A when the Smith method was used to define the categories. For the Turner method a larger number of neutral cases (category D)

TABLE 5.

Sigma E versus Pasquill Category for the Turner and Smith methods.

GRID TOWER	PASQUILL CATEGORY	TURNER METHOD N	TURNER METHOD $\bar{X}$	TURNER METHOD S	SMITH METHOD N	SMITH METHOD $\bar{X}$	SMITH METHOD S
South	D	126	3.20	2.50	81	2.92	2.40
North	D	125	3.36	2.50	79	2.69	1.79
South	C	100	6.48	3.98	98	5.42	3.97
North	C	102	7.18	3.83	102	5.93	3.65
South	B	35	10.64	4.79	76	8.02	4.78
North	B	35	10.65	5.79	74	8.78	5.21
South	A	0	-----	----	4	8.08	1.19
North	A	0	-----	----	4	10.20	1.30

TABLE 6.

Sigma A versus Pasquill Category for the Turner and Smith methods.

GRID TOWER	PASQUILL CATEGORY	TURNER METHOD N	TURNER METHOD $\bar{X}$	TURNER METHOD S	SMITH METHOD N	SMITH METHOD $\bar{X}$	SMITH METHOD S
South	D	126	7.98	7.63	85	6.96	7.06
North	D	126	8.36	7.52	83	7.10	6.40
South	C	107	12.54	9.95	105	11.00	8.84
North	C	105	13.39	8.76	103	12.23	8.81
South	B	39	20.10	13.83	76	16.88	13.13
North	B	37	21.73	14.90	75	16.62	12.71
South	A	0	-----	-----	4	18.20	7.21
North	A	0	-----	-----	4	23.23	3.23

occurred, while a greater number of quite unstable cases (category B) occurred when the Smith method was used. A comparison of Sigmas falling within the stability categories determined using the Smith and Turner Methods reveals systematically larger standard deviations in nearly all categories on both towers when the Turner method is employed to define the Pasquill stability category. A two factor analysis of variance procedure is used to determine the significance of variance differences between the stability categories (category factor) and between the Smith and Turner methods (method factor) in Tables 5 and 6. Only categories B, C, and D are used. Too few Sigma values fell within Pasquill Category A for inclusion in the variance analysis. Standard deviations (S) from Tables 5 and 6, with data from the North and South towers considered as replicates, were used in the evaluation. The analysis of variance was performed to test, at the 5% level of significance, whether there is (a) a difference between stability categories, and (b) a difference in the methods used to determine the stability categories. Tables 7 and 8 are the analysis of variance tables for Sigma E and Sigma A respectively.

Standard tables for the F distribution 95th percentile (5% level of significance) provide an F value of 5.14 for 2 degrees of freedom in the numerator and 6 degrees of freedom in the denominator (dF=2,6). This F value applies to the category factor and factor interaction rows of the Analysis of Variance Tables (Tables 7 and 8). For the method factor (dF=1,6), the 95th percentile F value is 5.99.

Analysis of variance proceeded first with an evaluation of interaction between categories and methods (third row of Tables 7 and 8). The interaction F values are small, (much less than 5.14) and are therefore insignificant. It is, therefore, reasonable to proceed with factor significant evaluations on the assumption that no interaction exists between the category and method factors.

The large F values for the category factor (first row, Tables 7 and 8) are well in excess of 5.14. These large F values are significant at the 1% level of significance. It is therefore reasonable to reject the hypothesis that no significant differences exist between stability categories. Calculated F values (second row, Tables 7 and 8) for the method factor exceed 5.99 only for Sigma A. For Sigma A, it is possible to infer a significant difference between the Smith and Turner methods used to classify Sigma A. Such an inference is not possible for Sigma E.

5. CONCLUSIONS

The analysis performed using the XM76 grid meteorological data indicates significant terrain influences. Terrain at distances well in excess of 100 times the tower height has a

TABLE 7.

Sigma E Analysis of Variance Table.

Variation	Degrees of Freedom (df)	Mean Square	F
Rows (categories) $V_a = 16.232$	2	$\hat{s}_a = 8.116$	57.683 df=2,6
Columns (methods) $V_c = 0.209$	1	$\hat{s}_c = 0.209$	1.485 df=1,6
Interaction $V_i = 0.050$	2	$\hat{s}_i = 0.025$	0.178 df=2,6
Subtotal $V_s = 16.491$	5		
Residual $V_r = 0.844$	6	$\hat{s}_r = 0.141$	
Total $V_t = 17.335$	11		

TABLE 8

Sigma A Analysis of Variance Table

Variation	Degrees of Freedom (df)	Mean Square	F
Rows (categories) $V_a = 88.789$	2	$\hat{s}_a = 44.394$	167.110 df = 2,6
Columns (methods) $V_c = 2.653$	1	$\hat{s}_c = 2.653$	9.986 df = 1.6
Interaction $V_i = 0.433$	2	$\hat{s}_i = 0.216$	0.815 df = 2,6
Subtotal $V_s = 91.875$	5		
Residual $V_r = 1.594$	6	$\hat{s}_r = 0.266$	
Total $V_t = 93.469$	11		

significant effect on measured tower turbulence. The effects of terrain or roughness elements along the periphery of test areas to a distance of at least 10 kilometers should be considered in an analysis of site turbulence measurements. Specific terrain influences noted for the XM76 grid include the following:

A. Under strong wind conditions (wind speeds in excess of 5 meters per second), large scale eddies due to Granite Peak wake effects make a significant contribution to the horizontal component of turbulence (Sigma A). These eddies may create enhanced horizontal meandering with wind directions from 180 to 290 degrees. This effect is not evident during light wind (2 meters per second or less) conditions.

B. The production of large mechanically induced eddies was minimized when winds were from 120 to 180 degrees because of the upward fetch over relatively uniform terrain. Sigma A/Sigma E ratios for this sector are independent of wind speed. Winds from this sector should produce the most consistent dispersion patterns.

C. Winds from the 290 to 120 degree sector, with sand dunes at a distance of several kilometers and the Cedar Mountains at a distance of 20 kilometers, did not produce as prominent wake effects as those from the 180 to 190 degree sector that included Granite Peak. However, the Sigma A/Sigma E ratio varies as a function of wind speed, indicating a significant terrain roughness influence. Dispersion effects from this sector would be less uniform than from the 120 to 180 degree sector.

Tower influences on meteorological data are often significant, and boom placement for meteorological sensor exposure requires careful consideration. Tower influences on the anemometer speed readings are not significant at low wind speeds, but become significant at high wind speeds. Tower shadowing decreases measured Sigma E values even at low wind speeds. Specific tower influences noted for the XM76 Grid include the following:

A. For wind from the 340 to 030 degree sector, the south tower meteorological equipment is in the tower shadow. South tower wind speeds from this sector average 9 percent below corresponding north tower wind speeds. For speeds below 2 meters/second, this effect ceases to be significant.

B. For winds from the 110 to 160 degree sector, the north tower meteorological equipment is in the tower shadow. North tower wind speeds from this sector average 9 percent below corresponding south tower wind speeds. The anemometer shadowing influence becomes insignificant for wind speeds below 2 meters/second.

C. No tower influence on wind speed was evident when winds

are from 030 to 110 degrees and 160 to 340 degrees. However, there was a 4 percent bias in the south/north tower wind speed ratio. This bias may have been due to differences in anemometer response.

D. Tower shadowing causes significant reduction in calculated values of Sigma E. The magnitude of this reduction appears to be 15 to 25 percent, although this estimate is considerably less certain than the wind speed reduction estimate. The tower shadowing effect appears to be less pronounced at higher wind speeds, due perhaps to the natural breakup of large eddies at higher wind speeds.

No significant difference was evident between the Smith versus Turner stability estimation methods for Sigma E categories, but a significant difference was found for Sigma A. The Smith method appears to be more effective than the Turner method, but a larger sample size, to include adequate Category A samples, is needed to perform a better comparison between these methods.

6. RECOMMENDATIONS

1. Studies of tower and terrain influences should be performed at all major test grids, particularly those where dispersion tests are executed.

2. Field anemometers intercomparisons are needed if wind profile data are to be used for wind gradient computations.

3. Tests of the Smith versus Turner stability estimation techniques should be repeated using an adequate Pasquill category A sample.

4. An additional methodology study should be done to optimize stability category estimation procedures at Dugway.

REFERENCES

Reference 1.

Turner, B.D., (1964): A diffusion model for an urban area. J Appl. Meteor., 3, 83-91.

Reference 2.

Smith, F.B. (1972): A scheme for estimating the vertical dispersion of a plume from a source near ground level. Proc. Third Meeting of the Panel on Air Pollution Modeling NATO/CCMS, No. 14, Brussels.

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